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VERSION WITH MARKINGS TO SHOW CHANGES MADE

[001] ELECTRIC MACHINE

[002] **FIELD OF THE INVENTION**

[003] The invention concerns an electrical machine, in particular, serving as an electric motor for a drive for vehicles ~~in accord with the generic concept of Claim 1~~.

[004] **BACKGROUND OF THE INVENTION**

[005] Machines of this type are mostly asynchronous machines, which are constructed with a stator within which a rotor is provided. The rotor is designed to be of the squirrel cage type and is made preferably of electrically conductive aluminum, which is precision cast to shape of the rotor. The aluminum, during the production, is poured into grooves formed by the laminate pack of the rotor. On the end of the rotor, the aluminum coils from the respective grooves are brought together into a ring, thereby forming the said squirrel cage winding. The asynchronous motors are predominately run under heavy duty circumstances and the heat generation of said motors calls for optimized cooling.

[006] For instance, such a machine has been disclosed by EP 0 484 548 B1. The with a rotor shaft and a rotor laminate pack and an externally located stator. This electrical machine is connected with the cooling system of the vehicle.

[007] A particular problem in the cooling of such an electric machine, is found in the method of bearings to support the rotor shaft, and in the sealing means. The temperatures transmitted from the rotor shaft to the bearings lead to bearing damage and concurrently, to the failure of the machine. Because of high temperatures in the rotor shaft, consequently, in the bearing sets, large temperature differences arise between the inner bearing ring and the outer bearing ring.

[008] At the same time circulation of a cooling medium in the electrical machine is made especially difficult by the limitations presented by the construction of the machine, This leads to the fact, that the generated temperatures, especially in the case of machines under heavy duty, can not easily be conducted away from the internals.

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[009] The present invention, then, has the purpose of proposing an electrical machine, in which the bearing system is protected from damage.

[010] ~~This purpose is achieved in accord with the invention by the features of Claim 1. Embodiments of the concept of the invention are described and explained as objects of the subordinate claims.~~

[011] **SUMMARY OF THE INVENTION**

[012] For the purpose of cooling, the heat generated by electrical machines, must be transferred to a cooling medium which can be transported to the individual machine. Air, is an advantageous cooling medium, which itself, after such use, can be cooled again or exchanged for free air. Air is an excellent insulator, so that in an electrical machine, on its account, no special insulation means need be called upon order to protect the various components of the machine against short circuit problems, which could arise from the characteristics of the cooling medium. In order to conduct the cooling medium into the machine safely, possible restrictions to flow must be avoided in every possible way.

[013] In accord with the invention, in an electrical machine, which possesses an externally disposed stator, an inner, rotatably, bearing supported rotor, a laminated rotor pack, and a rotor shaft, connected to rotate with the laminate pack, the rotor being hollow and internally placed and the rotor shaft is connected thereto by webs. The webbed shaft possesses on its circumference a number of webs, which in the interest of small heat transfer surface, lie against nearly line shaped contact surfaces on the laminated rotor pack. The webs are designed in such a manner, that they possess the necessary tensile strength and rigidity, but allow the least possible surface contact with the heat generating rotor laminate pack.

[014] An advantageous embodiment exhibits between the rotor laminate pack and the rotor shaft, a hollow interposed shaft, to which the said rotor laminate pack is affixed. In an advantageous embodiment, the cross sectional view of the rotor shaft is in the shape of a star, designed with four webs. Another advantageous embodiment shows the rotor shaft appearing in cross-section with three sickle shaped webs. One embodiment possesses webs, which are in the form of air-

conducting blades. In yet another advantageous embodiment, the webs are interrupted and do not lie with their entire length along the interposed shaft, i.e. the rotor laminate pack. Advantageously, the contact points are at the axial ends of the webs. In a further advantageous embodiment, the rotor shaft is made as a separate drop-forge part, or precision cast component and inserted int the hollow interposed shaft, i.e. the rotor laminate pack, by the attainment of a press fit. Advantageously, the rotor drafts are composed of a materials of poor heat conduction. These low heat conductivity shafts are preferably made of a high alloy steel or titanium.

[015] In a further advantageous embodiment, in the open space between the rotor laminate pack, i.e. the interposed hollow shaft, and the webs, a cooling medium can be conducted therethrough, which medium, preferably, would be air.

[016] **BRIEF DESCRIPTION OF THE DRAWINGS**

[017] The invention will ~~be more closely described with the aid of the illustrative figures. There is shown in~~**now be described, by way of example, with reference to the accompanying drawings in which**:

[018] Fig. 1 **is** an electrical machine with a star shaped, webbed shaft~~,~~**;**

[019] Fig. 2 **is** a cross-section through a webbed shaft an rotor shaft as in Fig. 1~~,~~**;**

[020] Fig. 3 **is** a cross-section through the heat exchanger, as in Fig. 1~~,~~**;**

[021] Fig. 4 **is** an electrical machine with a shaft having sickle shaped internal webs~~,~~**;**

[022] Fig. 5 **is** a cross-section through a webbed shaft and rotor laminate pack per Fig. 4~~,~~**;**

[023] Fig. 6 **is** an electrical machine with ventilating apparatus in the rotor shaft~~,~~**;**

[024] Fig. 7 **is** a cross-section through the webbed shaft and the rotor shaft as ~~per Fig. 6,~~**per**

[025] Fig. 8 **is** an electrical machine with a webbing arranged as an internal screw coil~~,~~**;**

[026] Fig. 9 **is** a cross-section through a heat exchanger which possesses a cooling basin~~,~~**;**

[027] Fig. 10 is a further cross-section through a heat exchanger with a cooling basin~~,~~;

[028] Fig. 11 is a cross-section through the cooling basin in accord with Fig. 9, and

[029] Fig. 12 is a cross-section through the cooling basin in accord with Fig. 10.

[030] DETAILED DESCRIPTION OF THE INVENTION

[031] Fig. 1 shows an electric machine 2 with a rotor shaft 4, which rotates in two sets of bearings, namely 6 and 8, which are enclosed in a housing 10. The rotor shaft 4 possesses a toothed end 11, proximal to bearing 4, by means of which the electrical machine 2 coacts with additional (not shown) elements of a line of drive mechanisms. In the housing 10 is placed a rotor, a stator laminated pack 12 through which a stator winding 14 penetrates. A rotor laminate pack 18, separated by a spacer opening 16, is situated radially within the said stator rotor laminate pack. The rotor laminate pack is penetrated by metal pins 20, which preferably are made of aluminum. A cap 24 is fastened onto the rotor laminate pack 18 with screws 22. As an alternative, the metal pins 20 can be embedded in the rotor laminate pack 18 in a precision molding operation. The rotor laminate pack 18 sits on an interposed shaft 26, circular in cross section. Within the said interposed shaft 26, the rotor shaft 4 is so placed, by press fit, that it rotates integrally with the interposed shaft 26. The rotor shaft can, however, be press fit directly into the rotor laminate pack. The rotor shaft 4 possesses four webs 28, which are arranged in the shape of a star (see Fig. 2). The webs 28, in the embodiment depicted here, show open spaces 29, so that the webs 28 do not lie along their entire length against the inner wall of the hollow interposed shaft 26. In the empty spaces 30 between the webs 28, a first cooling medium, preferably air, can be circulated through the interposed shaft 26, that is, for cooling the thereto connected rotor laminate pack 18. For this purpose, on an axial end of the rotor laminate pack 18, a ventilating fan 32 is placed, which brings about a flow of the cooling medium. On the other axial end of the rotor laminate pack 18, is provided a sheet steel ring 34, which directs the cooling medium flowing through a heat exchanger 36, without

part 40 of the housing. The cooling ribs 38 are limited as to outward extension by a cover 42, which is screwed onto the housing part 40.

[032] In the housing part 40, are provided cooling tubes 44, through which a second cooling medium flows. The heat absorbed by the first cooling medium in the heat exchanger 36 by means of the cooling ribs 38 and transferred to the cooling tubes 44, is there picked up by the second cooling medium of the electric machine 2 and transported away. At the same time, heat from the stator laminate pack (12) is transferred to the cooling tubes 44, whereby a cooling of the stator laminate pack 12 takes place.

[033] In the arrangement shown in Fig. 4, the electrical machine 2 exhibits a rotor shaft 4, which possesses three webs 46 bent into a sickle shape. This sickle shape, swinging form enables a high operational loading in regard to the tensile energy to be assumed by the press fit procedure of the webbed shaft 4 into the rotor laminate pack 18. For this purpose, settings and manufacturing tolerances can be evened out, that is, compensated for.

[034] The cooling tubes 48, in the embodiment shown here, are provided with a right angled cross-section. The bearing 50, which is constructed here as a roller bearing, possesses a grease cup placed within a cap 52.

[035] In Fig. 6, there is found within the interposed shaft 26 no webs at all, but rather ventilating apparatuses 54, whereby in the arrangement shown here, on each end of the interposed shaft 26 a device 54 is provided. The inner ring 56 of the ventilating apparatus 54, is by means of a toothed section 58, made to turn as one with the rotor shaft 4 (see Fig. 7). The outer ring 60 turns as one with the interposed ring 26 by means of a toothed section 62. The vanes 64 of the ventilating apparatus 54 transport the first cooling medium, again, preferable air, through the hollow interposed shaft 26, which is integral with the rotor laminate pack 18. The contact surfaces for the exchange of heat between the interposed shaft 26 and the rotor shaft 4, in this case, are very limited.

[036] The embodiment shown in Fig. 8, exhibits a rotor shaft 4, which is shaped in the manner of a screw conveyor. The web winds around a central shaft, and in this way, upon rotation, can forward the first cooling medium through the internal

hollow space of the interposed ring 26. Again in this case, the contact surfaces between the interposed shaft 26 and the rotor shaft 4 are in a quasi, linear-like surface along the web, so that the heat transmission can be held to a predominately low level. At the same time, as in all of the foregoing, described embodiments, the material of the rotor shaft 4 is so chosen, that a poor transmission of heat is assured. Among materials fulfilling this quality would be steel of high alloy content or titanium.

[037] In Figs. 9 to 12, different embodiments of the heat exchanger are described. In Fig. 9, the cooling tubes 44 are so arranged, that they are only embedded to the extent of a portion of their circumference in the housing part 40. The other portion of the circumference radiates the heat in the direction of the cooling ribs 38, which are placed in a cooling basin 66. The cooling basin 66 is connected to the housing 10, which, in turn, is cooled from the outside. Fig. 11 shows a cross-section through the heat exchanger 36 of Fig. 9. The cooling tubes 44 extend outward to approach the cooling ribs 38, so that the heat can be easily picked up. The cooling basin 66 is screwed onto the housing 10 with screws 68.

[038] Also, in Fig. 10, the cooling tubes 44 are so arranged, that only a portion of their circumferences are embedded in the housing part 40. The other part of the circumferential area radiates the heat present in the direction of the cooling ribs 38, which are placed in a cooling basin 66. The cooling basin 66 is connected to the housing 10. Cooling tubes 70, depicted here in dotted lines, are connected with the cooling tubes 44, which are to be found proximal to the cooling ribs 38. The cooling tubes 70 penetrate the cooling ribs 38 and cross the cooling tubes 44 at an angle of 90°. In this way, the cooling tubes 70 advantageously run through the cooling ribs 38 in a meander-like way and are connected at the beginning and end with the cooling tubes 44. The cooling tubes 70 can also be carriers of a throughflow of a low temperature cooling medium, which is fed from a source outside of the motor.

[039] Fig. 12 shows a section through the heat exchanger 36 in accord with Fig. 10. The cooling tubes 44 extend so far as to closely approach cooling ribs 38, so the heat can be well extracted therefrom. The cooling ribs here form a separate

cooler 72, which is placed in the cooling basin 66. The cooling ribs 38 are penetratively run through by the cooling tubes 70, whereby the flow of the second cooling medium in every two adjacent cooling tubes 70 is in a counterflow state. With the screw fastening 68 the cooling basin 66 is screwed onto the housing 10.

[040] Rotor and stator can be made in a compact manner of construction, and thereby a high utilization of the advantages of the machine can be attained. The electrical load data of the rotor in the invented machine are not affected. The manufacture of interposed shaft and the therein affixed rotor shaft is simple and economical. The heat transmission from the warm rotor laminate pack into the rotor shaft is substantially reduced. The temperature level at the various outside machine elements, such a bearings, or sealing means is markedly reduced.

[041] For various machines and applications, this *(heat removal)* effect is sufficient without additional ventilation, in order to reach the desired thermal values of the electrical machine.

Reference numbers and items

2 electrical machine
4 rotor shaft
6 bearing (rotor shaft)
8 bearing (rotor shaft)
10 housing
11 toothed section of rotor shaft
12 stator laminate pack
14 stator winding
16 an air gap between 12 and 18
18 rotor laminate pack
20 metal bar or pin
22 screwed connection
24 cap for 18
26 interposed shaft
28 web
29 opening to minimize heat flow
30 open space for cooling Fig. 2
32 ventilating fan (wheel)
34 a ring of sheet shell
36 heat exchanger
38 cooling rib
40 housing part
42 cover
44 cooling tube
46 web
48 cooling tube
50 gearing (Fig. 4)
52 cap for bearing grease pot
54 ventilating (cooling) apparatus
56 inner ring
58 toothed zone, Fig. 6
60 outer ring
62 toothed zone, Fig. 6
64 diffusor blades, Fig. 7
66 cooling basin
68 screw connection
70 cooling tube
72 cooler (Fig. 12)

<u>Claims</u>

Claimed is:

1. An electric machine (2) with an external stator and a rotor, which is inwardly situated and rotatably borne on bearings, and which electric machine possesses a laminate rotor pack (18) and a rotor shaft (4) connected thereto in a rotationally fixed manner, therein characterized, in that the rotor is hollow and the rotor shaft (4) is designed as a webbed shaft which exhibits on its circumference a plurality of webs (28, 46), which webs (28, 46) lie on nearly line-like touching surfaces on the laminate rotor pack (18) to form minimal heat transfer surfaces,

2. An electrical machine (2), in accord with Claim 1 therein characterized, in that between the rotor laminate pack (18) and the rotor shaft (4), a hollow interposed shaft (26) is provided, upon which the rotor laminate pack (18) is located.

3. An electrical machine (2), in accord with Claim 1 or 2 therein characterized, in that the cross-section of the rotor shaft (4) is designed in the shape of a star with four webs (28).

4. An electrical machine (2), in accord with Claim 1 or 2, therein characterized, in that the rotor shaft (4) is designed in the form of three sickle shaped webs (46).

5. An electrical machine (2), in accord with one of the Claims 1 to 4, therein characterized, in that the rotor shaft (4) possesses webs (28, 46) which are designed in the form of diffusor blades.

6. An electrical machine (2), in accord with Claim 1 or 2, therein characterized, in that the rotor shaft (4) is constructed in the shape of a screw conveyor.

7. An electrical machine (2), in accord with one of the Claims 1 to 6, therein characterized, in that the webs (28, 46) are interrupted and do not lie along their entire length against the interposed shaft (26), that is, the rotor laminate pack.

8. An electrical machine (2), in accord with one of the Claims 1 to 7, therein characterized, in that the rotor shaft (4) is produced as a separate forged

part or precision cast, and pressed into the hollow interposed shaft (26), i.e. the rotor laminate pack (18) to achieve a press fit.

9. An electrical machine (2), in accord with one of the Claims 1 to 8, therein characterized, in that the rotor shaft (4) is made of a material with low heat conductance.

10. An electrical machine (2), in accord with Claim 9, therein characterized, in that the material with low heat conductance is a highly alloyed steel.

11. An electrical machine (2), in accord with Claim 9, therein characterized, in that the material with low heat conductance is titanium.

12. An electrical machine (2), in accord with one of the Claims 1 to 11, therein characterized, in that in the zone between the rotor laminate pack (18), that is to say, the hollow interposed shaft 26, of the rotor shaft (12) and the webs (28, 46) a cooling medium may be circulated.

13. An electrical machine (2), in accord with Claim 12 cooling medium is air is therein characterized, in that the cooling medium is air.

ABSTRACT OF THE DISCLOSURE

Proposed is an electrical machine (2) with an external stator and an inward located rotor, rotatably borne on bearings, and which electric machine possesses a laminate rotor pack (18) and a rotor shaft (4) connected thereto in a rotationally fixed manner, the rotor is hollow and the rotor shaft (4) is designed as a webbed shaft which exhibits on its circumference a plurality of webs (28, 46), which webs (28, 46) for forming a minimal heat transfer surfaces, lie on nearly line-like touching surfaces on the laminate rotor pack (18) or on an associated interposed shaft 26.